FORECASTING OFFSHORE BROWN SHRIMP CATCH FROM EARLY LIFE HISTORY STAGES

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ABSTRACT

A prediction of adult brown shrimp harvest, based on an index derived from Galveston Bay bait fishery CPUE, is issued to the industry by the National Marine Fisheries Service Galveston Laboratory every June. This prediction has been the most reliable index of future shrimping success, but it is available only weeks before the shrimping season begins. Studies are underway to develop an earlier forecast by establishing valid abundance indices at the advanced postlarval and early juvenile stages of the brown shrimp life cycle.

Postlarval shrimp are sampled with a beam trawl twice weekly at the entrance of Galveston Bay. Predictions based on postlarval abundance have been quite variable, but the regular sampling yields information regarding timing and magnitude of shrimp immigration. Future work will attempt to improve predictions at this life stage, which would give the earliest information to the fishery.

Juvenile brown shrimp abundance has been evaluated at several Texas coastal ponds. Preliminary data from these mark-recapture studies suggest that there may be a relationship between juvenile shrimp standing stock and subsequent offshore abundance. If a prediction could be developed from juvenile stage shrimp it would be available as much as a month earlier than the bait index prediction.

INTRODUCTION

Biologists at the National Marine Fisheries Service (NMFS) Galveston Laboratory began studies in the early sixties to investigate possibilities of predicting the annual abundance of brown shrimp (*Penaeus aztecus* Ives). This work was based on the premise that the number of postlarval shrimp collected during their movement from the Gulf to coastal bays and the density of juvenile shrimp in estuarine areas are proportional to subsequent offshore densities of adult brown shrimp. Other fishery biologists, working under contract with the Galveston Laboratory or independently, have pursued the same approach along various parts of the Gulf and south Atlantic coasts. Detailed reports include those of Baxter (1963), St. Amant et al. (1963), Louisiana Wildlife and Fisheries Commission (1964), Christmas et al. (1966), St. Amant et al. (1966), Baxter and Renfro (1967), Berry and Baxter (1969), Christmas and van Devender (1981), and, most recently, Sutter and Christmas (1983).

In the Gulf of Mexico, brown shrimp postlarvae enter the bays and passes when they are 10 to 14 mm long. Mass movements of postlarvae into nursery areas generally occur in March and April after water temperatures reach or exceed 15.6 C (60 F). Collections of young postlarvae from the Galveston Entrance are used as early indicators of the upcoming crop for the offshore fishery. Shrimp abundance is measured as the postlarvae grow into juveniles and enter the bay and bait shrimp fisheries. Our best estimate of brown shrimp abundance is derived from data collected from the Galveston Bay bait shrimp fishery during May and early June.

The Gulf of Mexico shrimp fishery is one of the most valuable fisheries in the United States. Approximately half of the catch is landed in Texas. The annual shrimp catch is variable, however, and fluctuations in catch and value can cause economic hardship to the industry in poor years. Early prediction of offshore shrimp catch has become increasingly important to fishermen and processors so that they can plan their economic strategies in advance of the fishing season. Following, we describe how each life stage index is evaluated to form a prediction of offshore catch.

Postlarval Shrimp Abundance Index

A continuing survey to investigate seasonal changes in the movement of postlarval shrimp through the principal entrance to Galveston Bay (Fig. 1) began in November 1959 as part of an expanding shrimp research program. Initially, stations were located on Galveston Beach as well as at the Galveston Entrance to determine if the beach zone was a postlarval shrimp habitat. When no mean size difference was detected compared with Galveston Entrance samples, it was assumed that shrimp moved directly to estuaries. Shrimp near the shoreline of the entrance were sampled twice weekly with a hand-drawn beam trawl (Renfro 1963). Tows were made alternately in the morning and afternoon in an effort to sample during both ebb and flood tides each week. Penaeid shrimp were separated from the catch, identified, and counted at the laboratory. Details of sampling procedures and species identification were provided by Baxter (1963) and Baxter and Renfro (1967).

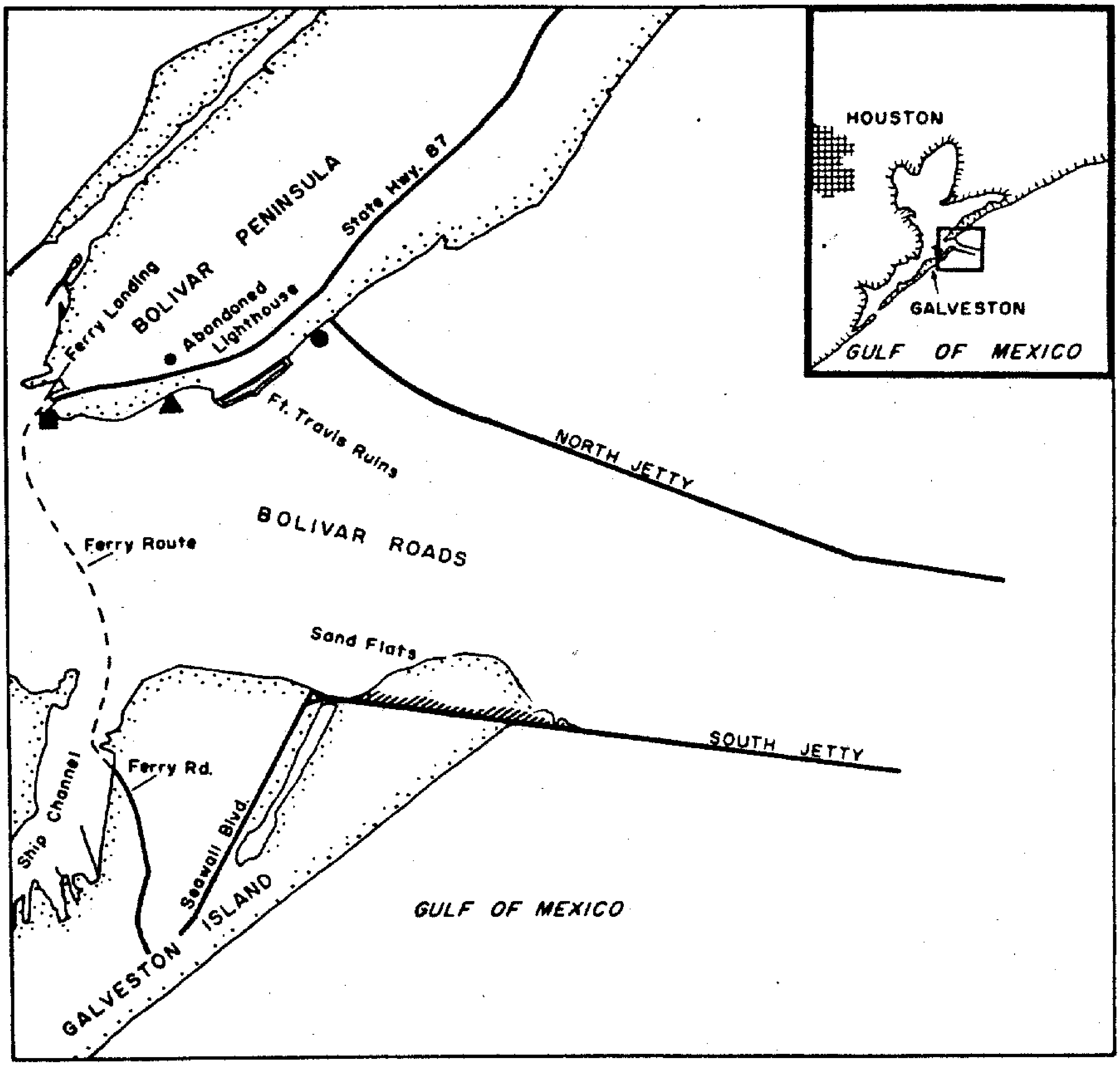

Figure 1. Postlarval brown shrimp sampling data site (filled black circle at North Jetty and Galveston Bay Entrance (from Baxter 1963).

The significance of postlarval catch gathered between November 1959 and May 1961 became apparent when we found high numbers of postlarvae caught in early spring 1960 were followed by a near record brown shrimp catch in the offshore commercial fishery during the summer months. Catches of postlarvae in 1961 were small as were later commercial harvests, suggesting that catch data on postlarvae were indicative of brown shrimp abundance.

Semiweekly sampling for postlarvae was initiated in August 1961 with a new objective - to investigate the possibility of predicting relative abundance of commercial shrimp from postlarval catches. Sampling procedures were not changed because we believed that a simple and inexpensive predictive technique would be more acceptable to shrimp management agencies than would complex sampling schemes. With the exception of a brief interruption caused by Hurricane Carla in September 1961, a routine schedule was followed until sampling terminated in November 1974. Sampling was again initiated in February 1983, continuing through May 1983, the months when brown shrimp enter Galveston Bay (Baxter and Renfro 1967).

Over the years, the postlarval index has provided a rough estimate of the number of postlarvae entering the bay system; however, it has not been a consistent indicator of future offshore abundance. Largest numbers of postlarvae are generally taken in March and April, declining in May, but abundance and timing vary year to year. For example, the 1983 postlarval counts were quite low compared with the 16-year (1960-75) average, and offshore catch also was low (Table 1). In contrast, 1963 counts were much higher than the 16-year average, but subsequent landings that year were less than the 1960-82 average of 27.5 million pounds. The 1967 total postlarval count was only about half of the 1963 count, yet the offshore catch was a record 42.7 million pounds.

Postlarval brown shrimp are most vulnerable to environmental conditions. They depend on the tidal and wind-driven currents to carry them into the bays and within the estuaries, and are subject to wide variation in salinity and temperature. Although postlarval brown shrimp can tolerate a wide range of temperature and salinity, the combination of low temperature and low salinity is detrimental (Zein-Eldin and Aldrich 1965). The postlarval index has great potential as a predictor if environmental variables can be quantified in the model and the prediction adjusted for changes in the variables. Sutter and Christmas (1983) showed that incorporating a salinity index, a salinity-temperature interaction index, and a postlarval shrimp index into a multilinear regression equation yields a model that accounts for 80% of the variability of June and July brown shrimp commercial harvest from Mississippi waters.

Table 1. Monthly average number of postlarval brown shrimp per tow at Galveston Bay Pass and subsequent offshore catch of adult brown shrimp.

	Averages 1960-75	1963	1967	1983
Feb	75	0	200	80
March	202	304	217	116
April	192	503	30	71
May	86	62	12	31
Subsequent Offshore Catch (10^6 lb)	27.5*	24.6	42.7	17.5

*1960-1982 average

Berry and Baxter (1969) examined several potential sources of variability: the reliability of their sampling gear, the effects of tides on postlarval catches, and the possibility of diel differences in catches. They found that the beam trawl provided a satisfactory sample, and that the total variation of samples taken over a 4-day period was almost as great as that from collections made during 6 months. In fact, the range in numbers of postlarvae at a given location can change from zero to several thousand within several hours. No correlations were found between postlarval catch and time of day or tide stage at the North Jetty location leading the investigators to believe that their station was probably in a position where water movements differed from recorded tide level. Collections of postlarvae made at Rollover Pass (East Galveston Bay) in spring 1965 showed that numbers of postlarvae varied with water movements when currents were strong. Berry and Baxter (1969) presumed that postlarvae caught during ebb tide had been carried into the bay on a previous flood tide, and that conditions affecting water flow can influence the numbers of postlarvae carried past the sampling station. These conditions may include tide changes, storms, and freshwater runoff from land.

Juvenile Brown Shrimp Standing Stock

We are currently evaluating the potential of juvenile brown shrimp population density in a Texas coastal pond as a predictor of offshore abundance. A predictor based on this pre-bait life stage would be more timely than the bait index prediction, though possibly not as accurate. This predictor would likely be more accurate than the postlarval index because of the lower amount of mortality occurring between the juvenile stage and entry to the fishery, but would be available somewhat later in the season.

The juvenile brown shrimp population of Sydnor Bayou, a tertiary tidal marsh in Galveston Bay, was first estimated from results of a Petersen mark-recapture study conducted before shrimp emigration from estuarine nursery areas to bay and offshore areas in May 1970. Mark-recapture experiments were conducted in June and July 1971 in five Texas coastal ponds from Galveston to the Port Lavaca area (Fig. 2). We returned to Sydnor Bayou in May 1983 to estimate standing stock of juvenile shrimp (Sullivan et al. in press).

There appears to be a direct relationship between juvenile population density and offshore abundance. Population densities for the three years studied were highest in years with above average offshore catch (1970 and 1971). The 1983 density in Sydnor Bayou was extremely low (37% of the 1970 level) and the prediction for the offshore catch was 9.7 million pounds less than the 1960-82 average

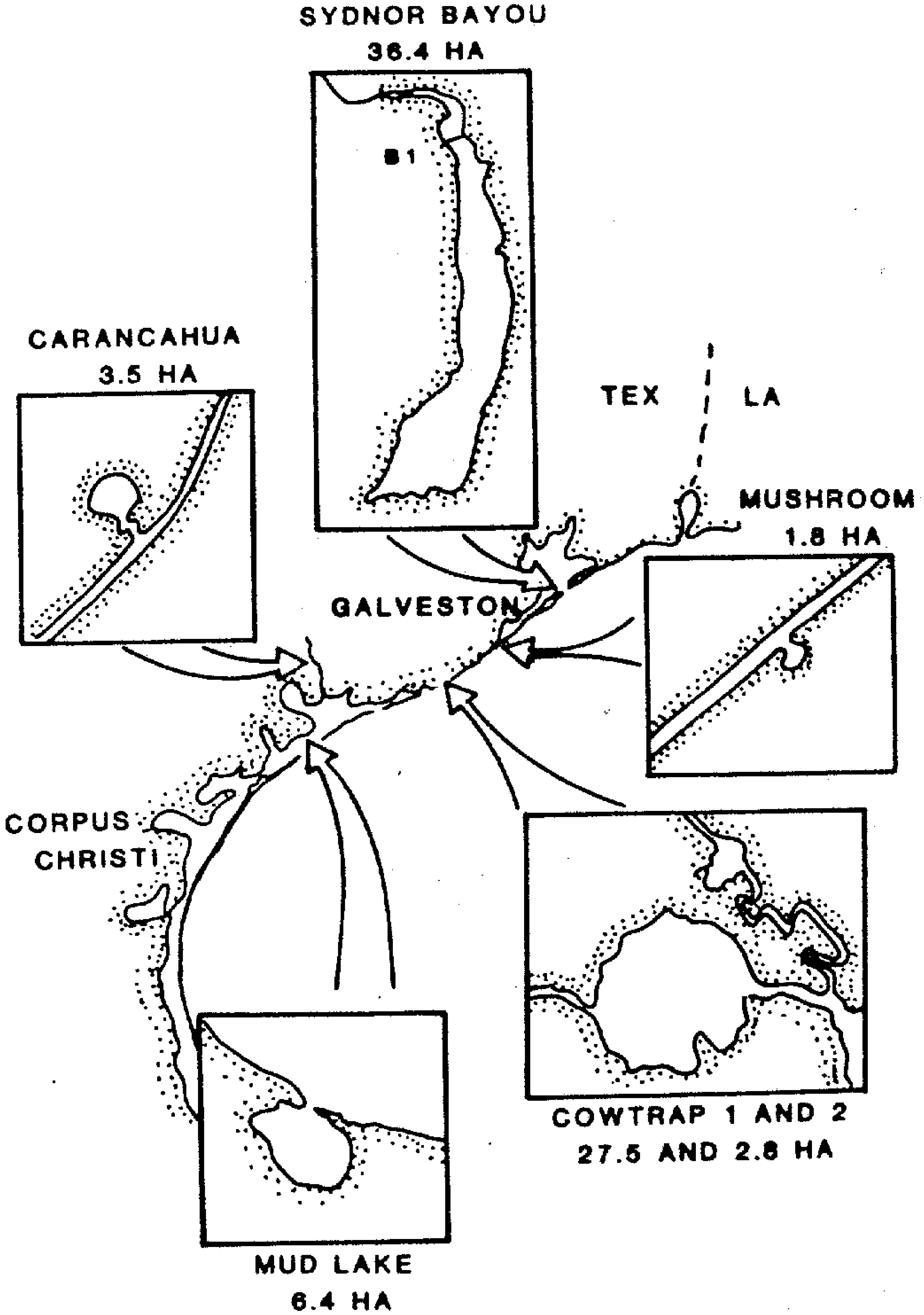

Figure 2. Sites of juvenile brown shrimp mark-recapture studies: Sydnor Bayou (1970, 1983); Carancahua, Mushroom, Cowtrap and Mud Lakes (1971) (from Sullivan et al. in press).

of 27.5 million pounds (Table 2). We do not have sufficient data to attempt a prediction using this index.

Bait Shrimp Index

Our most reliable index of future shrimping success is developed from the bait shrimp fishery data. Young shrimp grow to a size of 70 to 100 mm (total length) from 6 to 12 weeks after entering estuaries. These juveniles are harvested by a seasonal bait shrimp fishery which operates in Galveston Bay to supply sport fishermen with live bait. The shrimp are harvested with otter trawls towed by small trawlers.

A survey of the bait shrimp fishery of Galveston Bay began in 1957 (Chin 1960). Statistics of fishing effort have been gathered since June 1959, along with data on landings and species composition from five strata in the Galveston Bay system (Fig. 3). Interviews are obtained from at least half of the bait shrimp dealers and fishermen in the bay area, and visual check is made of other bait shrimp stands to determine how many are open for business. Total landings and fishing effort are estimated from this information. Species and size composition of landings are assessed from samples of shrimp purchased weekly from a random selection of dealers.

The bait index, derived from the average weekly catch per unit effort for the weeks including 25 April through 12 June, is directly related to the offshore catch (Fig. 4), with a correlation coefficient $r^2 = 0.847$ for data from 1960 through 1980. Bait index and offshore catch data for 1981 to the present are not included in the regression because the Texas Closure management measure has altered the fishing season since 1981. Bait indices for 1966, 1975 and 1979 were not included in the regression. CPUE's for 1966 and 1979 were inflated due to floods which may have concentrated shrimp in lower bay areas or forced early emigration. It was obvious early in the 1966 and 1979 seasons that the bait CPUE's were unrealistic. Weekly collections of bait samples showed an absence of bait in the upper bays, with unusually high catches in the lower bay. No data were collected in 1975.

Predictions from this model (Table 3) were very good for 1982 and 1983, and have been useful in evaluating the impact of the Texas Closure in 1981, 1982 and 1983 (Klima et al. 1982, 1983, and 1984). The assumption that the Galveston Bay bait fishery is indicative of the entire Texas coast is important to successful predictions. For example, in years such as 1973 when lower level abundance was due to heavy rainfall and runoff into the system and resultant lowered salinites, the bait index was low, and the prediction was therefore low. Subsequent production was 3.9 million pounds higher than

Table 2. Juvenile brown shrimp population estimates of shrimp larger than 40 mm TL for several Texas coastal ponds.

Location	Start Date	40 mm + population per acre	95% CI	Offshore Production (10^6 lb)
Sydnor Bayou				
90 Acres	5/31/83	2,309	2,010-2,608	17.5
	5/21/70	6,163	5,111-7,215	30.7
Mud Lake				
16 Acres	6/3/71	3,015	2,800-3,230	34.5
Carancahua				
9 Acres	6/7/71	6,314	5,753-6,874	34.5
Mushroom				
5 Acres	7/2/71	5,750	5,451-6,048	34.5

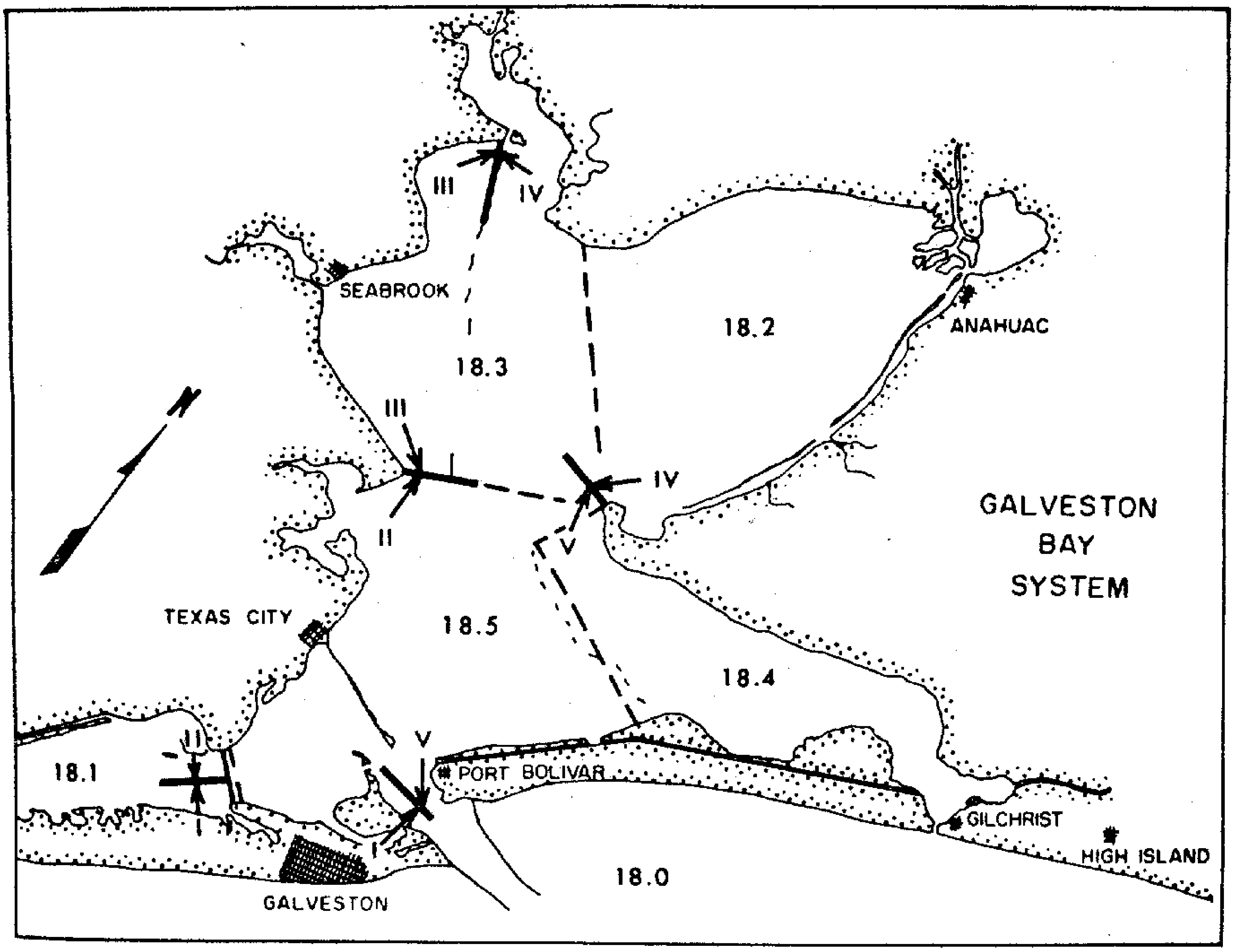

Figure 3. Statistical areas and five bait shrimp strata in Galveston Bay. Dealerships are grouped in geographic areas: I-Galveston Island (29 dealers); II-Virginia Point to Eagle Point (36 dealers); III-Eagle Point to Morgan Point (4 dealers); IV-Houston Ship Channel to Smith Point (6 dealers); and V-Bolivar Peninsula to High Island (23 dealers). Fishing areas are designated as: 18.1 - West Bay; 18.2 - Trinity Bay; 18.3 - Upper Galveston Bay; 18.4 - East Bay and 18.5 - Lower Galveston Bay. Numbers of dealers are for 1983.

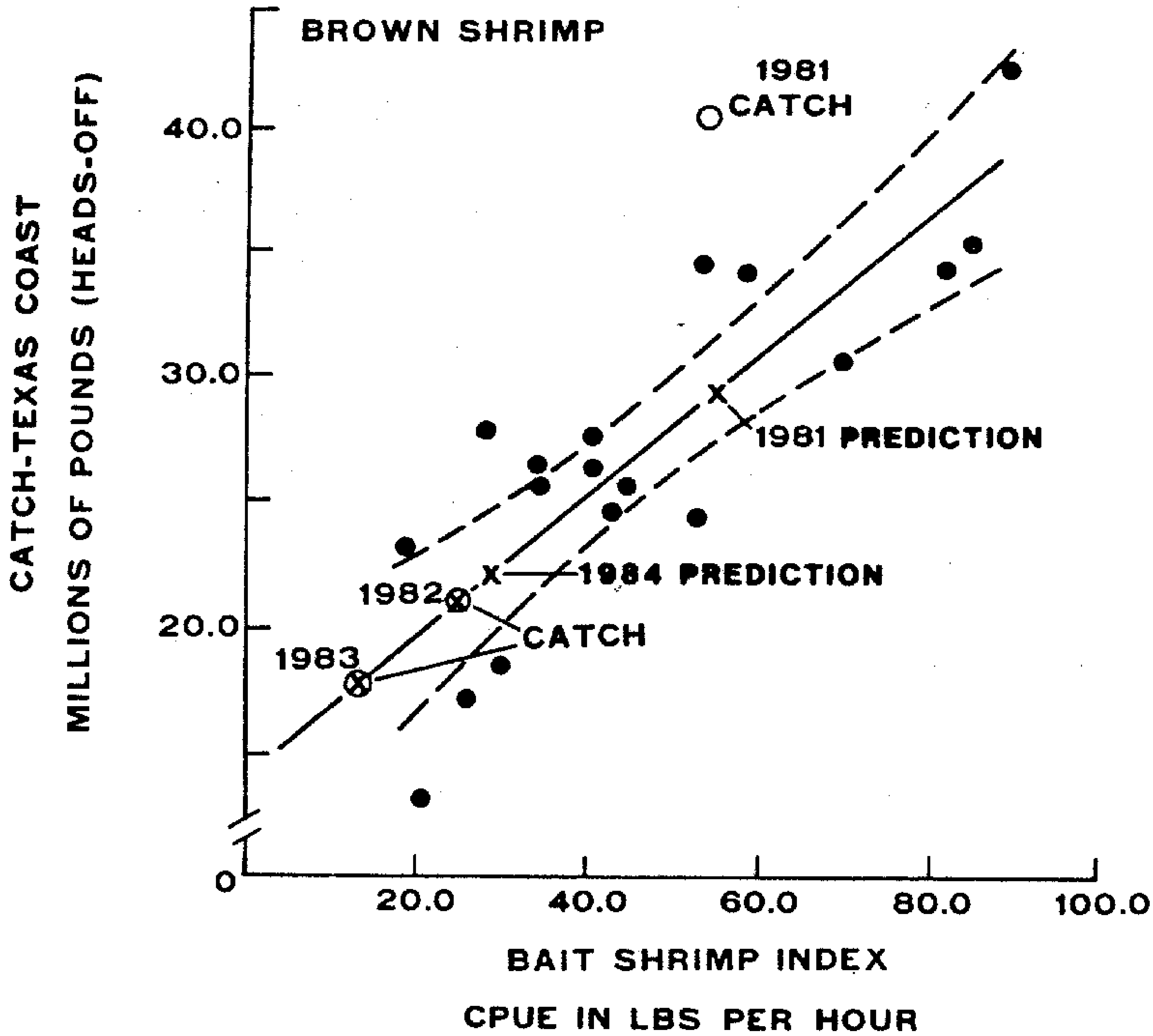

Figure 4. Bait shrimp index prediction model.

Table 3. Galveston Bay bait shrimp index from 1960 through 1983.

Year	Bait index	Texas Offshore Catch June-July (10^6 lb) Predicted	Actual	Difference (10^6 lbs.
1960	53.6	29.1	34.5	+ 5.4
1961	20.8	20.0	13.2	- 6.8
1962	26.1	21.5	17.3	- 4.2
1963	53.0	29.0	24.6	- 4.4
1964	30.2	22.6	18.6	- 4.0
1965	41.0	25.6	26.5	+ 0.9
1967	89.4	39.0	42.7	+ 3.7
1968	28.0	22.0	27.9	+ 5.9
1969	43.5	26.3	24.7	- 1.6
1970	70.0	33.7	30.7	- 3.0
1971	82.3	37.1	34.5	- 2.6
1972	85.6	38.0	35.5	- 2.5
1973	18.7	19.4	23.3	+ 3.9
1974	34.3	23.8	26.4	+ 2.6
1976	34.1	23.6	25.7	+ 2.1
1977	58.5	30.3	34.3	+ 4.0
1978	40.5	25.5	27.7	+ 2.2
1980	45.0	26.7	25.7	- 1.0
1981	54.3	29.3	40.0	+10.7
1982	26.3	21.5	21.8	+ 0.3
1983	12.7	17.8	18.2*	+ 0.4

*Preliminary data

predicted in 1973 because estuaries along the central and lower coast of Texas had good crops of brown shrimp and production was high in subareas 20 and 21, while the upper Texas coast (subareas 18 and 19) recorded the lowest catch ever up until that time.

SUMMARY

The three indices described here must meet three criteria to be considered "good" predictors. They must be precise, timely, and cost effective. The bait shrimp index is the most accurate predictor because the shrimp abundance is evaluated just prior to the offshore fishery season. Consequently, it is also the least timely. The bait index predictors have been fairly accurate; and the data collection is accomplished by one person. Because of the time factor, studies are underway to develop an earlier forecast by establishing valid indices at the advanced postlarval and early juvenile stages of the brown shrimp life cycle.

An index of postlarval abundance, while most satisfactory as an early predictor, is least accurate; however, the sampling itself is simple, requires one person's time and minimal equipment. Quantification of environmental effects may improve the accuracy of predictions from the postlarval index.

A prediction based on juvenile brown shrimp abundance is not as timely as the postlarval index, but more precision is gained. The mark-recapture method is labor intensive, but only for short periods of time, and requires more equipment than postlarval sampling. The accuracy of a prediction at this stage has yet to be determined because of limited data.

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